FEM Simulation of Vibroacoustic Analysis for Damage Scenarios of CFRP Used in Liquid Hydrogen (LH_2) Tank

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Background: LH_2 is commonly be stored cryogenically in tanks made from carbon fibre reinforced polymer, CFRP. Thermal cycles experienced by the tanks due to refueling of LH_2 can cause thermal fatigue, leading to delamination.

Vibroacoustic methods can serve as a potential costs-effective and non-destructive method for monitoring the CFRP tanks.

Figure 1. Airbus Zero E concept.[1]

Methodology: A simplified FE model of a real CFRP sample was created & tested in COMSOL Multiphysics, using Layered Shell Module to simulate delamination scenarios.

Simulated delamination had radii between 1mm to 5mm, measured up to 5kHz. The material properties will change with delamination, leading to a potential shift in natural frequencies.[2]

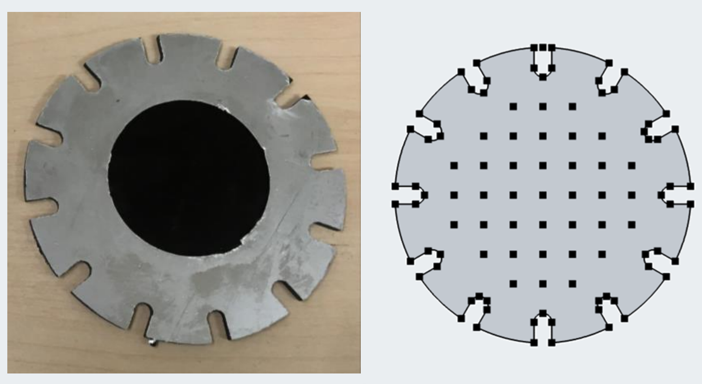


Figure 3. The real CFRP sample (left) & the FE model (right).

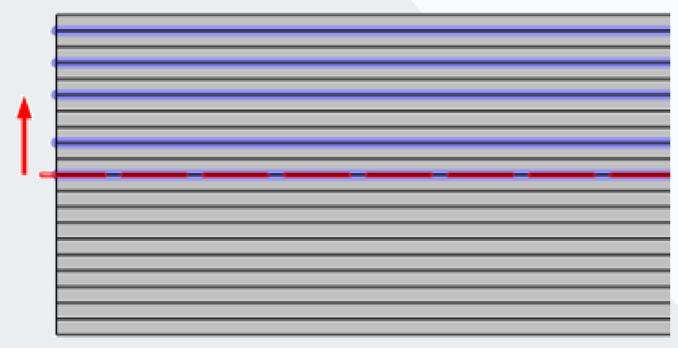
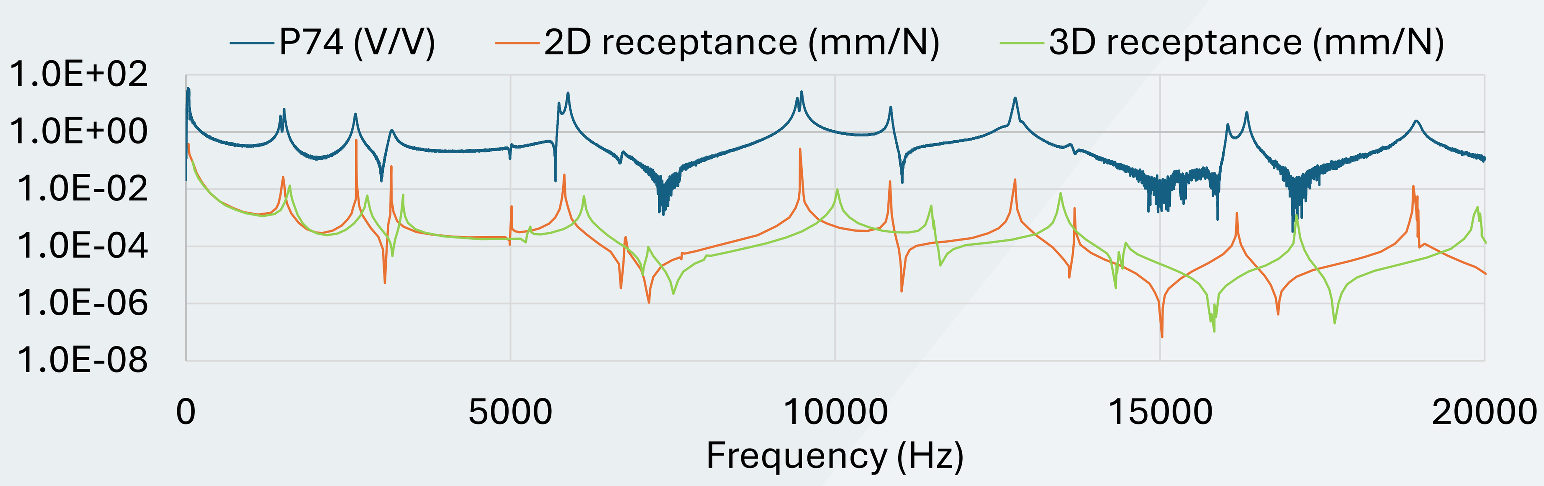
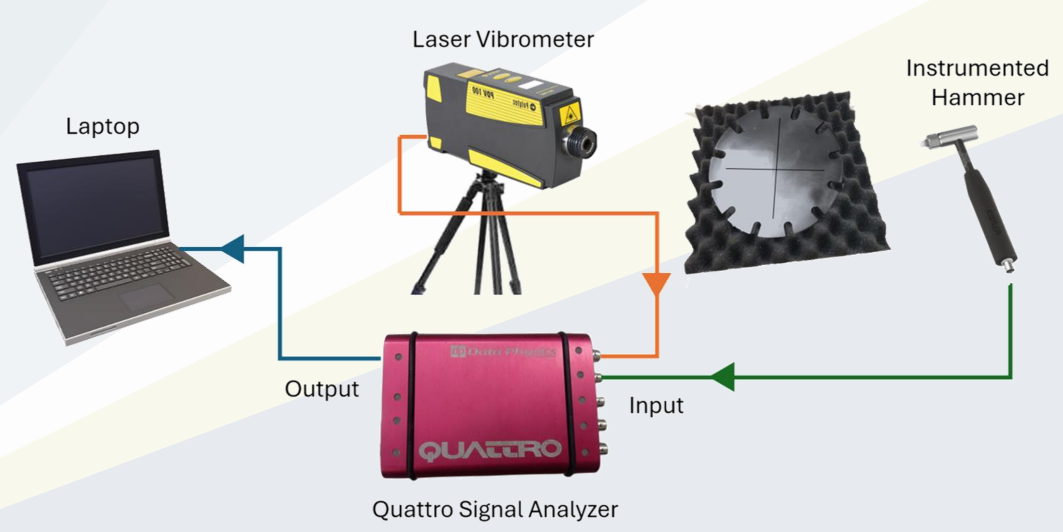


Figure 4. Specific delamination interfaces can be specified in COMSOL.

FE Model Validation: The accuracy of COMSOL was assessed with results from structural excitation of the real sample.



- Structural excitation was successfully performed on both stainless steel and CFRP samples, using a vibrometer and an instrumented hammer.
- COMSOL was able to simulate the response of both stainless-steel and CFRP sample, to a good degree of accuracy.

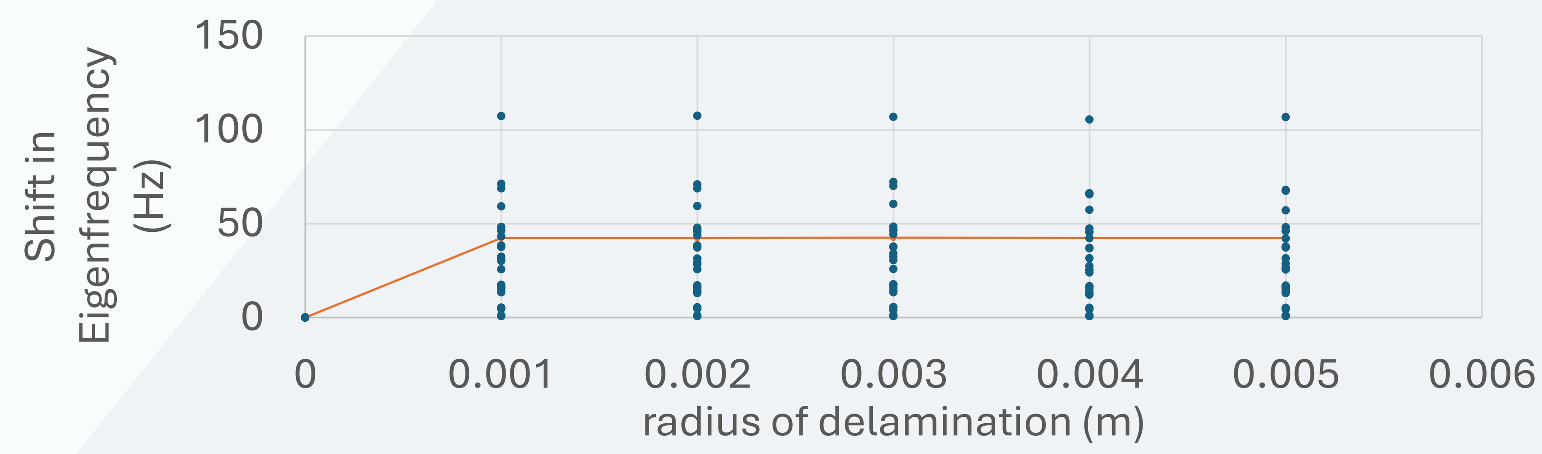


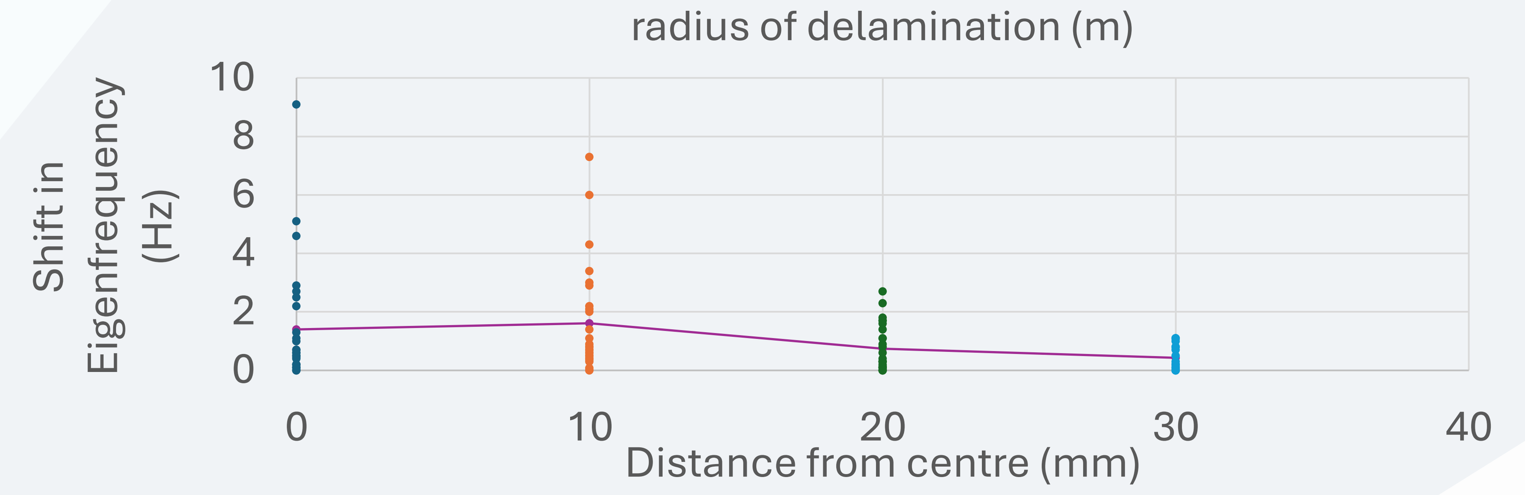
Aims:

- Verify results from FEA against measurements taken with vibroacoustic methods.
- Perform vibroacoustic FE analysis on a composite model at different stages of fatigue delamination.
- Analyse the feasibility of using shifts in natural frequencies to determine the severity of damage.

Results & Conclusion:

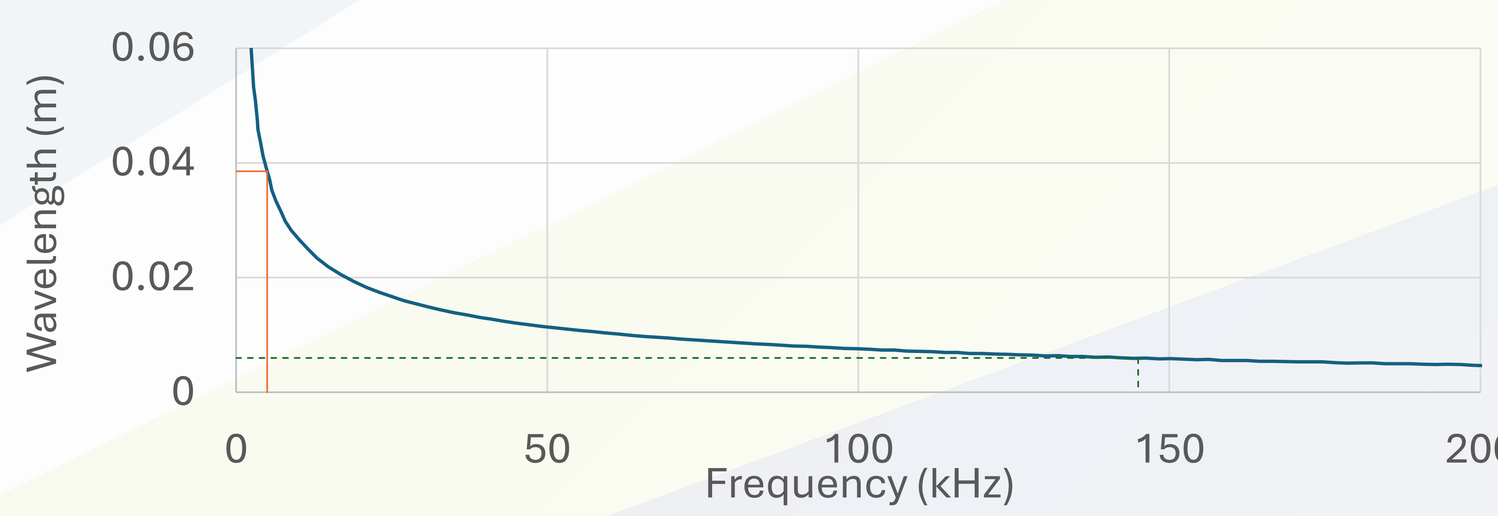
- COMSOL simulations indicted strong possibilities for detecting delamination at low frequencies, based on changes in natural frequencies.
- FE simulations to identify natural frequencies was found to be more time and resource effective, as compared to simulating receptance of a sample.
- Identifying changes in natural frequencies can serve as an early warning to changes in material properties due to damage/delamination.



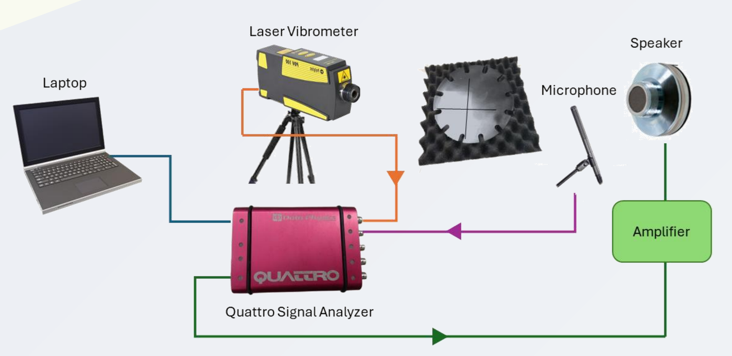


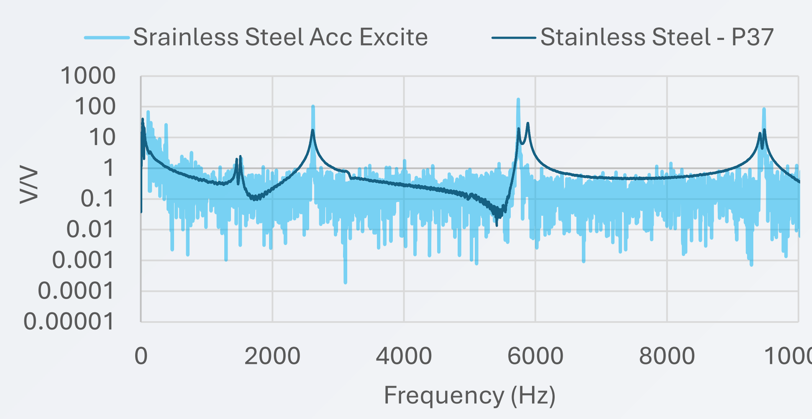
Potential Improvements: Size and location of delamination was difficult to determine at low frequencies.

- Higher frequencies (up to 160k Hz) with shorter wavelengths should be explored to properly capture the size of the delamination.[3]



- Attempt with acoustic excitation proved unfeasible due to noise observed in the results.





[1] Airbus. "How to store liquid hydrogen for zero-emission flight." (accessed 2024).
[2] M. Stache, M. Guettler, and S. Marburg, "A precise non-destructive damage identification technique of long and slender structures based on modal data," *Journal of Sound and Vibration*, vol. 365, pp. 89-101, 2016, doi: 10.1016/j.jsv.2015.12.013.
[3] I. C. London. "Disperse." https://www.imperial.ac.uk/non-destructive-evaluation/products-and-services/disperse/ (accessed 2024).

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